COLMAC MECCA PLANT

MECCA, CALIFORNIA

THERMAL DeNOx OPERATING & MAINTENANCE MANUAL

1.0

INTRODUCTION

1.1 GENERAL

This document describes the Thermal DeNOx system installed on two ABB/Combustion Engineering circulating fluidized bed boilers located at the Colmac Mecca facility in Mecca, California.

The combustor systems are circulating fluidized bed, drum type, steam generators with design conditions of 230,000 lb/hr of steam at 1,270 psig and 925^{o}F each. The combustors burn agricultural waste (agri-waste).

Agri-waste is charged to the combustors and is combusted in a fluidized bed. Particulate laden flue gases travel upward through the combustion chamber. At the top of the chamber, the flue gases flow into a cyclone and the cleaner flue gases exit overhead. Ammonia is injected into the cyclone dome. As the ammonia leaves the injection nozzles, it expands as a free jet inside the cyclone, mixing with the flue gas thereby promoting the Thermal DeNOx reaction. Flue gases then flow through a duct to the rear convection pass that is constructed of membrane walls. Located in the rear convection pass are the heat recovery sections consisting of superheater, economizer and primary and secondary air preheaters.

This document is intended to assist operators of the Thermal DeNOx system, the plant maintenance staff and others seeking a general understanding of the plant from a systems standpoint. In addition to reading this document, one should read the manufacturer's operating instructions for each system component before attempting to operate the system. Operating personnel should also be familiar with the operation of similar equipment and observe all safety practices normally related to power plant equipment and DeNOx system equipment.

The performance data used in this document is based on design specifications and process modeling studies. After acquiring operating experience, set points and limits may be changed to optimize the process. At that time, appropriate revisions to this document may be generated.

PROCESS OVERVIEW

Basically, the system involves the storage and vaporization of liquid ammonia (LNH_3), and injection of the ammonia vapor, VNH_3, into the cyclone through multiple injection ports. As the ammonia leaves the injection nozzles, it mixes with the flue gas and promoting the Thermal DeNOx reaction. The process is diagrammed on Drawing ESA-101, Process Flow Diagram, Ammonia System.

Liquid ammonia is brought on site by trucks with an on board NH_3 vapor compressor or LNH_3 pump that is used to transfer LNH_3 to the storage tank.

The LNH_3 is stored in a 33 ft long x 8 ft diameter storage tank, with a volumetric capacity of 12,000 gals. gross, 9,840 gals. net. To ensure adequate supply of VNH_3 is available for the process, one 50 kW vaporizer is provided, which is automatically energized to vaporize LNH_3 when pressure in the storage tank is low. The vaporizer is located at an elevation lower than the bottom of the storage tank so it is gravity filled with LNH_3. Ammonia vapor from the head space of the tank is injected into the cyclone through injection nozzles.

The purpose of the vaporizer is to maintain a vapor pressure in the storage tank above 45 psig, which is the vapor pressure of LNH_3 at 30°F. Because of the large surface area of the storage tank, heat input to the system from the vaporizers will not be required except during times of low ambient temperature (near 30°F). At 30°F, the vapor pressure of LNH_3 is 45 psig, which approaches the minimum pressure required for full-demand ammonia delivery. The VNH_3 flows from the storage tank to each boiler. The branch line to each boiler contains a pressure control valve, flow element and flow control valve before the four 1" injection lines branch off. Each of the four injection lines includes a manual valve, injection hose, and an engineered discharge nozzle.

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SECTION 2.0

OPERATIONAL DESCRIPTION

NOx emissions from the Colmac Mecca plant will be maintained at low levels by maintaining proper circulating fluidized bed operation, low combustion temperatures and by using the Thermal DeNOx Process System.

The purpose of the Thermal DeNOx system is to reduce nitrogen oxide (NO_x) emissions in the boiler flue gas over the operating load range. The system, as designed, involves injection of ammonia (NH_3) in the "appropriate" temperature zone (approximately 1650^{o}F) of the cyclone. Reaction of NH_3 with NO_x results in the formation of non-polluting nitrogen and water.

The Thermal DeNOx system consists of the following subsystems and components which will be discussed in this section:

- One ammonia storage tank, V-101
- One liquid ammonia vaporizer, E-101
- Ammonia injection system
- Piping, fittings, valves, instruments and controls

The liquid anhydrous ammonia (LNH_3) storage tank is a 12,000 gallon (gross capacity), uninsulated carbon steel pressure vessel. American National Standards Institute (ANSI) Standard K61.1 and CAL OSHA specifies that the tank fill capacity should be limited to eighty-five percent of total volume. The maximum fill has therefore been set at 9,840 gallons (82% of gross capacity).

There is one normal flow out of the LNH_3 storage tank:

Ammonia vapor (VNH_3) to process: VNH_3 flow to the cyclones is regulated by the VNH_3 flow control valves one for each unit as described in Section 4.0.

There are two intermittent flows out of the NH_3 storage tank:

1. LNH_3 to vaporizer: This flow is controlled by vaporizer operation as described in Section 4.0.

2. VNH_3 to tank filling system: This flow is controlled by operation of the LNH_3 truck's on-board ammonia vapor compressor/liquid ammonia pump.

There are two intermittent flows into the NH_3 storage tank:

1. VNH_3 from vaporizer: This flow is controlled by vaporizer operation as described in Section 4.0.

2. LNH_3 from tank filling system: This flow is controlled by LNH_3 truck's on-board ammonia vapor compressor/liquid ammonia pump.

As shown on Drawing PID-100, each of the five lines described above is protected with an excess flow control valve. An excess flow control valve is a spring loaded device that will close when too much flow passes through the valve. Excess flow control valves do not shut off tight, but continue to leak through a small internal orifice. In the event of a line rupture, an excess flow valve will prevent large quantities of NH_3 from suddenly being discharged to atmosphere. Manual valves are provided downstream of each excess flow control valve for tight shut-off.

The tank vent, drain, and instrument pressure connections are also fitted with excess flow control valves in addition to manual isolation valves.

Two, 100 percent ASME listed pressure relief valves, PSV-3770A&B which are set at 265 psig provide tank over-pressurization protection. The valve capacity was sized in accordance with Appendix A of ANSI K61.1, and California Title 8, Subchapter 1, Article 4, paragraph 511. A full port, three-way selector valve provides "on line" maintenance capability for these relief valves.

Local tank instrumentation includes two level indicators: LI-3777 and LI-3778; a pressure indicator, PI-3774; and a temperature indicator, TI-3776. LI-3777 is a fixed tube level indicator, which consists of an internal tube with the opening at the 82% level and a small (No. 54 drill) opening with a plugged connection. If the level transmitter fails or is suspected of failing, the plug should be removed from LI-3777 to check liquid ammonia level in the storage tank particularly during or immediately after a filling operation. If LNH_3 is discharged, the tank is filled to or beyond the legal capacity. LI-3778 is similar to LI-3777 except it is a rotary level indicator not a fixed tube. To manually determine the level with LI-3778, one opens the vent valve and slowly rotates the indicator handle until the release changes from vapor to liquid. At that point the volumetric fill can be read from the dial faceplate. Like LI-3777, LI-3778 discharges through a No. 54 drill opening.

CAUTION: Anyone removing the plug from LI-3777 or LI-

3778 must wear SCBA gear and protective clothing, and follow all safety procedures described in Section 10.0.

Remote tank instrumentation includes a differential pressure type level transmitter LT-3779; a pressure switch HI-HI, PSHH-3773; a pressure transmitter, PT-3772; and a temperature element (RTD), TE-3775.

Under normal DeNOx system operating conditions with the DeNOx system operating at full capacity (140 pph normal ammonia flow, 200 pph maximum) approximately two weeks service is expected with a maximum allowable fill. Tank level should, however, be maintained above 25% full and in no case be allowed to drop below 10% full.

Filling the tank is performed using the ammonia vapor compressor aboard the LNH_3 trucks. LNH_3 is off-loaded from the truck by pressurizing the head space in the truck with compressed vapors withdrawn from the NH_3 storage tank. The resulting pressure differential forces LNH_3 from the truck to the storage tank. Ammonia loading in the storage tank can be performed without affecting system operation.

Manual isolation valves,two with remote cable actuation, and thermal relief valves are provided in the filling lines.

One horizontal, electric vaporizer rated at 50 kW is used to maintain pressure in the NH_3 storage tank during periods of low ambient temperature (near $30^{o}F$). Heat transfer from the outside air will eliminate the need to operate a vaporizer until the tank liquid temperature drops below $30^{o}F$. The vaporizer is mounted such that the heater core is below the minimum liquid level in the NH_3 storage tank. Refer to Section 4.0 for vaporizer control details.

The vaporizer discharges ammonia vapors back to the storage tank. Manual isolation valves are provided in the liquid inlet and vapor outlet lines. ASME listed pressure relief valve, PSV-3757, provided in the ammonia vapor line between the vaporizer and storage tank set at 265 psig provides overpressure protection for the vaporizer.

Vendor furnished vaporizer auxiliaries include isolation valves, inlet wye strainer, SP-104, pressure relief valve, PSV-3757, local pressure indicator, PI-3755 and local control panel (CP-101) with vendor standard interlocks.

The Ammonia injection system consists of ammonia piping, valves and controls as described herein.

Ammonia vapor exits the storage tank through an excess flow valve, a manual isolation valve and a fail closed, diaphragm actuated, on/off control valve, FV-3780. FV-3780 will remain open, allowing VNH_3 flow to process only if all the permissives that assure safe operation are satisfied. Refer to Section 4.0 for details.

The ammonia supply line to process splits into two branches, one to boiler number 1 and the other to boiler number 2. In the remainder of this manual, the tag numbers for boiler number 1 will be used, but the description is also applicable for boiler number 2. The corresponding boiler number 2 tag numbers may be shown in paranthesis.

Pressure control valve, PCV-1751 (2751), regulates the VNH_3 pressure to each boiler in order to ensure consistent, repeatable operation of the ammonia flow control valve located downstream.

A V-cone style differential pressure flow element, FE-1753 (2753), is used to measure the total VNH_3 flow to each boiler.

A diaphragm actuated, modulating flow control valve, FCV-2753, which is equipped with manifold isolation and bypass valves to be used in the event of a controls failure, controls the flow of VNH_3 to process.

SECTION 3.0

DESIGN CRITERIA
MAJOR EQUIPMENT

- Ammonia Storage Tank, V-101

Quantity:	One
Design:	265 psig at 165^{O}F
Code:	ASME Sec. VIII, Div. 1
Capacity:	12,000 gallons gross 9,840 gallons net
Nominal size	8 ft. dia. x 28'-11" SS length

- Ammonia Vaporizer, E-101

Quantity:	One
Design:	265 psig
Capacity:	200 pph NH_3 at 100%
Code:	ASME Section VIII, Div. 1
Connected kW:	50 kW
Electrical Supply:	480 VAC, 3 phase

SECTION 4.0

CONTROLS DESCRIPTION

The controls and interlocks for the Thermal DeNOx system are described in this section. The description includes the specific controls and interlocks for each piece of equipment and each process control loop. The overall concept of the instrument control scheme is shown on ESA Drawings ICS-100 through 104. The electrical control schemes of all electrically operated equipment are shown on ESA drawings. (E-300 through E-305.)

1a. Vaporizer Automatic Mode (i.e., Storage Tank Pressure Control):
Vaporizer, E-101, maintains a minimum storage tank pressure at setpoint 40 psig, based on a 4-20 mA DC signal from the storage tank pressure controller, PIC-3772. In automatic mode, the pressure controller constantly checks and updates the 4-20 mA DC signal based on the storage tank pressure, and sends to the appropriate signal to the vaporizer SCR controller to maintain the storage tank pressure at, or above, the setpoint. The Storage Tank Pressure controller PIC-3772 used for vaporizer control is a single element, closed loop, proportional and reset controller. In manual mode, the operator can vary the output from the pressure controller PIC-3772 to vary the output from the vaporizer.

Permissives: (i.e. enable vaporizer operation).

a. Automatic operation selected (Manual-Off-Automatic Switch HS-3751B on vaporizer control panel).

b. Ambient ammonia not HI-HI (AE-3792A-C).

c. Storage tank pressure not HI-HI (PSHH-3773).

d. Storage tank level not LO-LO (LT-3779).

e. Storage tank temperature not HI-HI (TE-3775).

f. Vaporizer heater core temperature within limits (High-high temperature controller mounted in the vaporizer control panel).

To Start: (i.e., enable operation)

a. Local panel (HS-3751B) should be switched to "Auto".

b. The DCS switch (HS-3751A) from control room should be in enable position

c. The vaporizer heaters will be turned "ON" and "OFF" by the 4-20 mA signal from PIC-3772.

Stop/Trip:

a. From Local panel by turning "OFF" HS-3751B.

b. Manual Stop from DCS in control room via HS-3751A.

c. Automatic trip on ambient ammonia HI-HI (AE-3792A-C).

d. Automatic trip when storage tank pressure is HI-HI (PSHH-3773).

e. Automatic trip when ammonia level in the storage tank is LO-LO (LT-3779).

f. Automatic trip when ammonia storage tank is HI-HI (TE-3775).

g. Automatic trip when heater core temperature is HI-HI (vaporizer control panel temperature controller).

h. Main circuit breaker trip on vaporizer heater overload/ short-circuit.

Alarms:

a. Storage tank pressure LO (PAL-3772).

b. Storage tank pressure HI (PAH-3772).

c. Storage tank pressure HI-HI (PAHH-3773).

d. Storage tank temperature LO (TAL-3775).

e. Storage tank temperature HI (TAH-3775).

NOTE:
Storage tank pressure and/or temperature LO alarms signify that the vaporizer(s) heat input is inadequate to meet the process demand. Conversely the pressure and/or temperature HI alarms signify that the ambient heat transfer and/or vaporizer heat input is exceeding the process demand.

1b. Vaporizer Manual Mode:

To Start:

a. Local panel (HS) should be switched to "manual". Permissives are the same as in automatic operation. All other permissives are bypassed. In manual, the vaporizer will fire at full output, 50 KW.

2. Vaporizer Isolation Valves (FV-3766 and FV-3769)

Automatic shut-off valves (FV-3766 and FV-3769) are located in the LNH_3 supply line to the vaporizer and the VNH_3 return line to the storage tank respectively. Both valves are solonoid controlled diaphragm operated and designed to fail close on loss of air or electrical power.

Permissives: (i.e. valves remain open).

a. Ambient ammonia is not HI-HI (AE-3792A-C) refer to ICS-102.

Close/Trip:

a. Locally using HS-3766B.

b. From control room using DCS HS-3766A by giving close signal.

c. Automatically when ambient ammonia is HI-HI (AE-3792A-C).

To Reset (Open) Both Valves

a. The operator will have to reset using DCS HS-3766A switch from control room.

3. Process VNH_3 Isolation Valve (FV-3780).

An automatic shut-off valve (FV-3780) is located in the VNH_3 line from the storage tank to the process pipe lines. The valve is solonoid controlled diaphragm operated and designed to fail close on loss of air or electrical power (Refer to ICS-102).

Permissives: (i.e valve remains open).

a. Ambient ammonia is not HI-HI (AE-3792A-C).

b. Boiler not tripped (DCS).

Close/Trip:

a. Locally using HS-3780B.

b. From control room using DCS HS-3780A by giving close signal.

c. Automatically when ambient ammonia is HI-HI (AE-3792A-C).

d. Automatically on boiler trip (DCS).

To Reset (Open) The Valve:

a. To reset (i.e. open) the valve, the operator will have to reset using DCS HS-3780A switch from the control room.

4. VNH_3 Pressure Control: Setpoint = 37.5 psig

VNH_3 is pressure regulated to ensure consistent repeatable performance of the DeNOx system. PCV-1751 (2751) is a self-contained pressure regulator.

5. VNH_3 Flow Control: Setpoint varies with load (see ICS-104).

A VNH_3 flow control valve, FCV-1753 (2753), regulates the VNH_3 flow to the DeNOx system. FCV-1753 (2753) controls the VNH_3 flow to the DeNOx system based on a 4-20mA signal from FIC-1753 (2753). In automatic mode, the flow controller continuously compares the VNH_3 flows measured by flow element FE-1753 (2753) against the calculated setpoint updating the output as required. This controller is a closed loop, proportional and reset controller. The calculated setpoint (i.e., VNH_3 flow demand) is the output of an "internal" summer. One input to the summer is the programmed VNH_3 demand based on boiler load as measured by steam flow. The second input to the summer is the output from a proportional controller which constantly checks and updates its output as necessary to maintain the NOx emissions equal to the programmed NOx emissions, which are based on boiler load as measured by steam flow. The output of the internal NOx controller is held within $\pm 10\%$ limits to prevent over-controlling the VNH_3 flow.